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PB-290 320

Ground-Based Sulfur Dioxide Measurements within a Copper Smelter Plume - Anaconda, Montana

(U.S.) Environmental Monitoring and Support Lab, Las Vegas, NV

Sep 78

United States
Environmental Protection
Agency

Environmental Monitoring
and Support Laboratory
P.O. Box 15027
Las Vegas NV 89114

EPA-600/4-78-055
September 1978

Research and Development

PB 290320

EPA

Environmental Monitoring Series

Ground-Based Sulfur Dioxide Measurements Within a Copper Smelter Plume– Anaconda, Montana

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/4-78-055		PB290320

4. TITLE AND SUBTITLE	5. REPORT DATE
GROUND-BASED SULFUR DIOXIDE MEASUREMENTS WITHIN A COPPER SMELTER PLUME - ANACONDA, MONTANA	September 1978
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
J. Jeffrey van Ee	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Environmental Monitoring and Support Laboratory Office of Research and Development U. S. Environmental Protection Agency Las Vegas, Nevada 89114	1AD606
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
U. S. Environmental Protection Agency - Las Vegas, NV Office of Research and Development Environmental Monitoring and Support Laboratory Las Vegas, Nevada 89114	Final Report, 10/76-3/77
	14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Monitoring Operations Division (MOD) of the Environmental Monitoring and Support Laboratory - Las Vegas developed a mobile sulfur dioxide (SO_2) instrument package for use in the remote, rugged terrain surrounding The Anaconda Company's copper smelter at Anaconda, Montana. The self-contained instrument package was used to obtain ground-level SO_2 measurements in the area impacted by the smelter plume. Wind speed, wind direction, and temperature were also recorded at the sampling site. The requirement for the package to be quickly deployed in an area impacted by the smelter plume necessitated the use of a helicopter to sling-load the package into position. Calibration of the instruments was performed before and after each sampling period.

The primary area of interest for SO_2 measurements was the mountainous terrain south of the smelter. During the 4 active months of the study, the package was deployed 17 times. The primary and secondary SO_2 standards were exceeded on a number of occasions. Source emission strength estimates, obtained by EPA-Region VIII are presented for those times when SO_2 was measured at a site. These data can be used to normalize the recorded SO_2 values to account for the varying SO_2 emissions from the source.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Anaconda, Montana	13b
Sulfur Dioxide	Copper Smelter	07b
Meteorology	Rough Terrain Monitoring	04b
Air Pollution and Control	Mobile Monitoring	68a

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	87
	20. SECURITY CLASS (This page)	22. PRICE
	UNCLASSIFIED	A05 - A01

EPA Form 2220-1 (9-73)

*U.S. GOVERNMENT PRINTING OFFICE: 1978 - 684-009/1902-H, 2026, 9-I

EPA-600/4-78-055
September 1978

GROUND-BASED SULFUR DIOXIDE MEASUREMENTS WITHIN A COPPER SMELTER PLUME - ANACONDA, MONTANA

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OFFICE OF RESEARCH AND DEVELOPMENT
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LAS VEGAS, NEVADA 89114

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FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound monitoring data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report presents part of the results of an air monitoring study in Anaconda, Montana that was designed to provide information on smelter plume dispersion in the remote areas around the Anaconda Company copper smelter. Using a specially developed sulfur dioxide instrument package deployed by a helicopter, ground-level sulfur dioxide measurements were made within the smelter plume. These data can be used in conjunction with other data to develop mathematical plume dispersion models. Further information, not provided in this report, may be obtained from the Monitoring Operations Division of the Environmental Monitoring and Support Laboratory.

George B. Morgan
Director
Environmental Monitoring and Support Laboratory
Las Vegas, Nevada

PREFACE

At the request of the U.S. Environmental Protection Agency, Region VIII, the Environmental Monitoring and Support Laboratory - Las Vegas conducted a study of The Anaconda Company's copper smelter in Anaconda, Montana, from October 1976 to March 1977. The purpose of the study was to define plume parameters for use in a mathematical plume dispersion model.

Three distinct data sets were identified as being essential for the refinement of the plume dispersion model. Double theodolite pibal measurements were made throughout the study period to obtain initial wind profiles in the vicinity of the plant. Airborne in-plume measurements of sulfur dioxide (SO_2) and particulates (b_{scat}) were obtained using an instrumented H-34 helicopter. These measurements were used to define the plume dispersion characteristics. (Data from these two studies will be released by the Environmental Monitoring and Support Laboratory in a separate report.) A mobile sulfur dioxide instrument was used to obtain ground-level readings within the plume in order to better define the impact of the plume on the surface. The results from the mobile SO_2 instrument study are contained in this report.

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LIST OF ABBREVIATIONS, SYMBOLS AND CONVERSIONS

ABBREVIATIONS

°C	-- degrees Celsius
°F	-- degrees Fahrenheit
hr	-- hour
°K	-- degrees Kelvin
kg	-- kilogram
km	-- kilometer
lbs	-- pounds
lpm	-- liters per minute
m	-- meter
mi	-- miles
mm	-- millimeters
mph	-- miles per hour
$\mu g/m^3$	-- micrograms per cubic meter
ppm	-- parts per million
s	-- second
AC	-- alternating current
AGL	-- above ground level
DC	-- direct current
Hg	-- mercury
SO_2	-- sulfur dioxide

SYMBOLS

>	-- greater than
~	-- approximately
<	-- less than
≤	-- less than or equal to

CONVERSIONS

°C = 5/9 °F 32
°F = 9/5 °C + 32
°K = °C + 273.16
1 lb = 0.45 kg
1 m = 3.28 feet 1 mi = 1.6 km
1 mph = .45 m/s

INTRODUCTION

The State of Montana and The Anaconda Company have been monitoring air quality in the locale of the Anaconda copper smelter for years using a network of sulfur dioxide monitors. Violations of the primary and secondary sulfur dioxide (SO_2) standards have been documented by both monitoring networks. The amount of control required has been estimated using a mathematical dispersion model and the data from the two monitoring networks. Although data from the networks is useful in assessing the impact of the smelter operation for a particular site, the magnitude and frequency of violations of the air quality standards projected for areas which have no monitoring stations have been sharply debated. Of major concern is the mountainous area south and west of the smelter (Figure 1). The probability that the plume will strike the ground in the vicinity of the smelter is highest in these areas because of the high ground elevations relative to the top of the stack. Thus, the most significant violations of ambient air quality standards have been predicted for the area south and west of the smelter.

At the time of the study three monitoring sites were located to the south of the smelter. One site is located on the Mill Creek valley floor and the other two are located on "C" Hill (Figure 1). These sites are of little value in assessing the impact of the plume in the area to the south of the plant when the plume blows over, or around, the monitoring site.

The U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory-Las Vegas developed a mobile SO_2 instrument package specifically for use in those areas not covered by the present monitoring networks. The self-contained package was designed for rapid deployment by helicopter to those areas where the plume could be seen impacting the ground. Wind speed, direction, and temperature were also measured with the package. Calibration of the SO_2 instrument was performed at the site.

SUMMARY

The instrumentation package was deployed seventeen times during the four months of observing the plume. Violations of the Federal primary and secondary SO_2 standards were recorded in the valley lying to the northeast of the plant and in the mountainous terrain to the south of the plant. The highest values were recorded near the Continental Divide to the south of the plant.

The complex wind patterns in the area of the smelter made it quite difficult to predict the behavior of the plume. On several occasions the plume was observed to be gradually blown toward the ground, but by the time it was possible to deploy the package, the plume was observed blowing towards a different area. These instances, as well as those times when it was impossible to deploy the package because of darkness or bad weather, are briefly noted. In many instances, photographs were taken to record the occurrence of the plume touching the ground.

Considering the limitations of a fixed station monitoring network, the stochastic nature of the plume and the rugged terrain, the helicopter-deployed instrument package proved to be useful in documenting ground-level concentrations of sulfur dioxide in remote areas. Three violations of both the Federal primary and secondary SO_2 standards were recorded.

GENERAL PROCEDURES

The Anaconda smelter plume was observed, throughout the study, from the Fairmont Hot Springs Resort 10.9 kilometers (6.8 miles) southeast of the Anaconda stack. When the plume was observed hitting the ground, particularly in those areas not covered by the existing monitoring networks (Figure 1), an EPA Huey (UH1H) helicopter was called in from Butte, Montana, to pick up the mobile SO_2 montoring package located at the motel. Typically, the helicopter arrived at the motel within 20 to 45 minutes after the telephone call. The package was sling-loaded (Figure 3) to the area of interest. At the site, the package was quickly assembled and calibrated prior to the collection of the ambient air data (Appendix E).

With the helicopter, it was possible to quickly place the package in virtually any area around the smelter. Steep mountain slopes and areas with dense forest cover were the only areas that were inaccessible to the helicopter. Permission for placement of the package on private and public lands was obtained prior to the commencement of the project. Restricted visibility and turbulent weather were the only other limiting factors governing the use of the helicopter to position the instrument package. Fortunately, use of the helicopter was not restricted by snow cover (Figure 4), since snowfall was unusually light during the study period.

When the plume was no longer observed blowing towards the monitoring site, the helicopter and crew returned to the site. After the package had been calibrated and disassembled, the package was either carried to another site, or returned to the motel. Data from the portable weather station, and the sulfur dioxide instrument, were reduced in the field to the fullest practical extent and further analyzed after the completion of the project (Appendix G). Custody of the data was the responsibility of the project officer.

CHRONOLOGY

During the study, the plume was observed striking the ground on a number of occasions. The dates of those occurrences are listed in Tables 1 and 2. The mobile SO_2 monitor was used on 17 different occasions (Figure 2) when it appeared to be practicable to obtain ground-level plume impaction measurements. In many instances, particularly when it was impossible to sample the plume impacting the Mill Creek valley area, photographs were taken to document the ground impaction episode. Figures 5 to 17 depict some of the more interesting episodes which are briefly described in Tables 1 and 2.

TABLE 1. OBSERVED INSTANCES OF THE ANACONDA PLUME IN THE MILL CREEK VALLEY AREA, OCTOBER 12, 1976 - FEBRUARY 24, 1977

October 14, 1976	The plume was observed by the H-34 crew to be impacting to the lee of the saddle between "C" Hill and Weather Hill. Measurements were made at this time using the H-34.
October 17, 1976	The plume blew into the valley for much of the day. A snowstorm reduced visibility to the point where it was unsafe to deploy the mobile SO_2 instrument in the area.
October 21, 1976	The plume shifted into the valley at approximately 1630 hours and continued blowing into the area until approximately 2200 hours. Not enough daylight remained for the mobile SO_2 package to be deployed.
November 10, 1976	The plume was observed to be blowing into the Mill Creek valley at 0700 hours. The mobile SO_2 sampler was positioned at Site #5 (Figure 2). By approximately 1000 hours the plume had shifted off the site. By 1500 hours, the plume had lifted and shifted to the west so that it was no longer hitting the ground. Twelve passes were made [70-100 feet Above Ground Level (AGL)] with the H-34 over the mobile SO_2 instrument package as the plume shifted off Site #5.
November 11, 1976	The plume was observed by the H-34 crew to be hitting the ground in the vicinity of Grassy Mountain. By the time the Huey helicopter was available to position the mobile sampler, the plume had shifted towards the west. At 1430 hours the plume began to bend towards the valley. By the time the helicopter was in position to move the mobile sampler, the plume had shifted back towards the west. The box was positioned at Site #7 (Figure 2) for the night. Examination of the data shows the plume hitting that area during the night.
November 12, 1976	The plume was observed, by the H-34 crew, to be hitting the ground at Site 8 (see map) early in the morning. The box was moved from Site #7 to Site #8 where high SO_2 readings (13.1 ppm) were observed. At the time measurements were being taken, the main part of the plume had lifted and shifted to the west. Thus, the high readings were obtained in a remnant of the plume.

(Continued)

TABLE 1 (Continued).

	At 1145 hours the plume was observed impacting the top of Grassy Mountain. Later, it lifted over the top of the mountain.
November 14, 1976	At 1600 hours the plume was observed blowing over the "C" Hill - Weather Hill saddle. Not enough daylight remained to position the SO_2 instrument. A photograph of the plume was taken. At 1717 hours the plume had shifted back to an easterly direction.
November 18, 1976 - December 7, 1976	No observations were made during this time because the Huey helicopter was down for maintenance. The H-34 portion of the project was inoperative during most of this period.
December 17-26, 1976	Christmas break - no documented observations were made during this period. The pibal group did report observing the plume blowing into the Mill Creek valley during this period.
December 29, 1976	At approximately 1600 hours the plume began to blow over the saddle formed by "C" Hill and Weather Hill. At approximately 1700 hours the plume began blowing back towards the east. A photograph was taken to document the phenomenon.
	At approximately 1700 hours the Huey helicopter was used to position the SO_2 instrument at Site 14 (Figure 2). Remnants of the plume were observed at this time in Mill Creek canyon. Some SO_2 was detected at this site a few hours after sampling began. This coincides with the observation (made from the Fairmont) that the plume was blowing into the Mill Creek valley at 1930.
December 30, 1976	At 0730 hours the plume was observed blowing into the Mill Creek valley. At 0900 hours the helicopter was used to obtain pictures of the plume impact prior to calibrating the SO_2 package at Site 14. By the time the instrument had been calibrated, the plume had shifted towards the west so that it was flowing over the saddle between "C" Hill and Weather Hill. The SO_2 instrument was placed at Site 15 and readings were taken for approximately three hours. Readings no higher than 2 ppm were obtained

(Continued)

TABLE 1 (Continued).

	at this site. In an effort to get higher readings in the plume, which appeared to be in a canyon to the east, the package was moved to Site 16 (Figure 2) for the night.
December 31, 1976	Low clouds and snow prevented the Huey crew from checking the operation of the SO_2 instrument. Occasionally, throughout the day, the clouds broke and the plume was observed blowing into the Mill Creek valley.
January 1, 1977	Clouds and light snow showers obscured the stack during the early morning. By mid-day the clouds had cleared to where the plume was observed blowing out over the valley. The instrument package was retrieved at this time.
January 7, 1977	Scattered snow showers were in the area throughout the day. At approximately 1500 hours the clouds had cleared to where the plume was observed blowing into the Mill Creek valley - Willow Creek area. The plume continued blowing in that direction until sometime during the night. The EPA-Washington decision to ground the Huey, due to an EPA H-34 helicopter crash, prevented the helicopter crew from deploying the box.
January 8, 1977	At approximately 1600 hours the plume appeared to be going over the "C" Hill - Weather Hill saddle into the Mill Creek area. Photographs were taken to document this condition which lasted for approximately 30 minutes.
January 11, 1977	The Huey helicopter operation was suspended until the H-34 helicopter crash investigation was completed.
January 31, 1977	The Huey helicopter operation was resumed. At 1600 hours the plume began to enter the Mill Creek valley area over the saddle to the south of the plant. Approximately one hour later the plume began to blow towards the north-east.
February 5, 1977	At 1730 hours small amounts of pollution from the plume could be seen sliding into the Mill Creek valley area. At 15 the plume was viewed heading over the area where Site 16 had been located. The onset of darkness prevented siting the SO_2 package and made it difficult to clearly see where the plume was headed. By 2200 hours the plume was clearly blowing towards the north.

(Continued)

TABLE 1 (Continued).

February 8, 1977	Remnants of the plume were observed over the Site 16 area at daybreak. They appeared to be at a fairly high elevation. The plume was observed at 0730 hours to be rising towards the North at a high elevation angle. The plume was stable. Winds were light. At approximately 1130 hours the plume was observed blowing towards Deer Lodge and then back towards the southwest. The plume was observed hitting Mount Haggin in the Clear Creek area. Site 17 was chosen as a compromise. The main portion of the plume appeared to be hitting the ground in the lower portion of the draw; however, the tree cover was heavy, and it was not possible to position the box in the area. Site 17 was chosen because it appeared as if some of the pollution trapped in the draw would eventually be blown up to the instrument. Also, the plume height appeared to be rising as the day progressed, and it appeared as though the light winds might blow the plume into the site. By 1330 hours the winds had picked up from the south to such an extent that the plume was being blown strongly towards the north. At approximately 2100 hours, the plume was observed blowing over the town of Anaconda in the same pattern observed from approximately 1000-1100 hours that morning.

TABLE 2. OBSERVED INSTANCES OF THE ANACONDA PLUME IMPACTING THE GROUND OUTSIDE OF THE MILL VALLEY AREA

October 26, 1976	The plume was observed hitting a ridge southeast of the smelter in the afternoon. The portable SO_2 package was positioned in this area (Site #1).
October 29, 1976	Downwash brought the plume down into the tailings ponds. The H-34 "cross-sectioned" the plume in this area. Two low-level passes were made (100 feet AGL) along the road east of the tailings ponds adjacent to the plant.
November 1, 1976	Downwash brought the plume into the tailings pond area. The H-34 was unable to complete a cross section of the plume before it shifted.
November 5, 1976	Downwash brought the plume to the ground 2 1/2 miles southeast of the plant. Two cross sections were flown in the area. One of the cross sections was developed over the mobile SO_2 instrument that had been deployed at Site #3.
November 15, 1976	Downwash brought the plume into the tailings pond area northeast of the plant. A cross section was developed over the mobile SO_2 instrument located at Site #10.
November 16-17, 1976	Downwash from the mountains southwest of the smelter caused the plume to impact the ground between 1 1/2 and 4 miles northeast of the plant. Cross sections were flown at various distances within the plume impaction area. The mobile SO_2 package was located at Site #11 following the report from the H-34 that the highest SO_2 values were obtained in this area.
December 8, 1976	The plume touched ground approximately 2 miles northeast of the stack. Two cross sections were developed.
December 10, 1976	Strong winds brought the plume down to the ground near a power sub-station located to the east of the plant. The mobile SO_2 package was located at Site #13.
February 12, 1977	The plume appeared to be hitting the mountains to the east of the motel at approximately 1200 hours. (By the time the helicopter arrived from Butte the plume had shifted towards the northeast.) The hills in the vicinity of the Butte VORTAC station (Figure 2) were no longer

(Continued)

TABLE 2 (Continued).

	in the plume path. Since a close observation of the plume was not possible until approximately 1200 hours, it is difficult to define the persistence of the plume in that area.
February 10, 1977	Strong winds accompanying a Pacific front blew the plume to the ground northeast of the plant. Blowing dust and a shortage of personnel prevented placing the package on the valley floor.
February 12-17, 1977	Emissions from the smelter were quite light during this period since the electric furnace was shut down. The plume was not observed hitting the mountainous areas during this period (the areas of primary interest). Little interest existed for placing the instrument package on the valley floor with the present plant operating conditions even though there appeared to be times when the plume may have touched the ground.
February 18, 1977	Strong westerly to southwesterly winds existed throughout the day. Periodically in the afternoon, the plume appeared to be looping down to the ground east of the smelter (in the vicinity of the Mount Haggin ranch). At 1610 hours the plume was reported curving towards the southeast over the Fairmont Hot Springs Resort. Measurements in the vicinity of the resort indicated that the concentration was approximately 0.3 ppm. By the time the instrument package was ready to sample ambient air at the selected site the winds had shifted and lightened.
February 20, 1977	Winds were from the southwest throughout the daylight hours. Winds were light in the morning, and increased during the afternoon. Emissions were light. During the afternoon, the plume appeared to touch the ground southeast of the smelter.
February 22, 1977	Cloudy skies and westerly winds were the rule for the day. Occasionally, winds were from the southwest, or the northwest. During the afternoon, the plume rise was zero. Occasionally, puffs of smoke appeared to hit the ground to the east of the smelter. Measurements with the mobile SO_2 package confirmed the fact that puffs of the plume were hitting the ground. The recorded SO_2 measurements did not warrant setting up the box at a particular location.

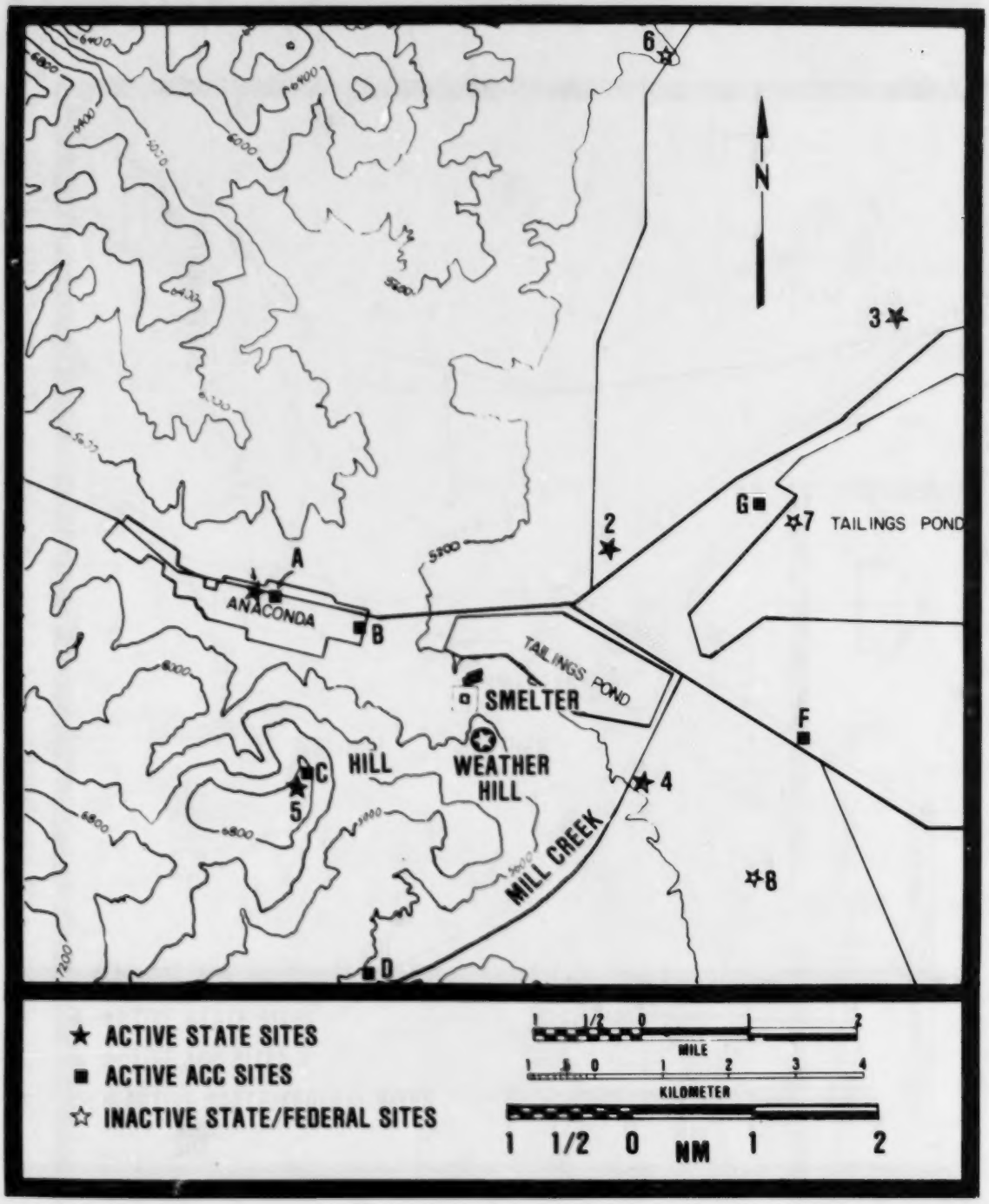

FIGURE 1. Air monitoring site locations, Anaconda Montana.

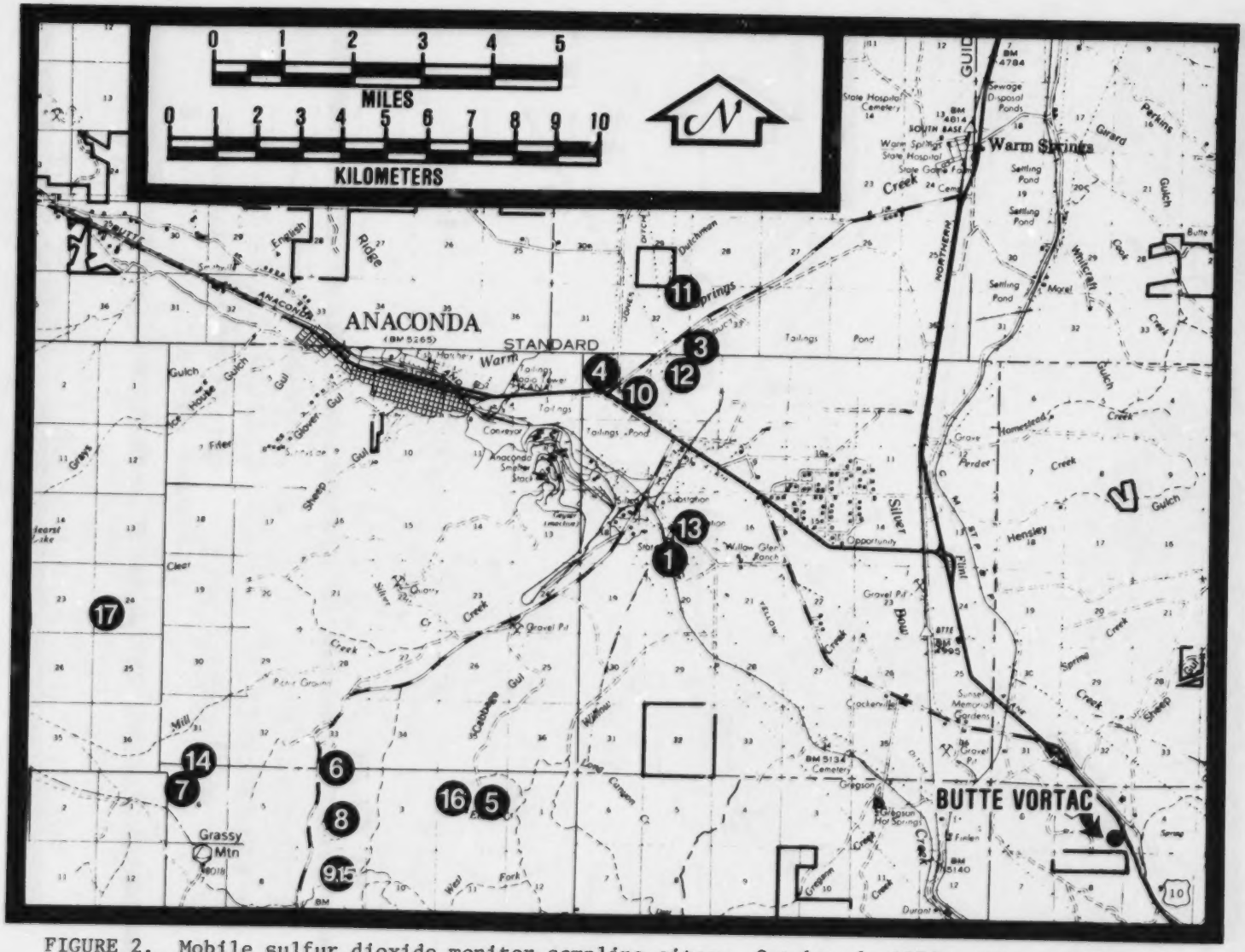

FIGURE 2. Mobile sulfur dioxide monitor sampling sites. October 6, 1976 - February 25, 1977.

FIGURE 3. The Huey helicopter slings the mobile sulfur dioxide instrument package to a remote site.

FIGURE 4. Site 16, January 1, 1977, approximately 1300.

FIGURE 5. The Anaconda plume impacting the Mill Creek valley area early in the morning, November 10, 1976.

FIGURE 6. An aerial view of the Mill Creek valley in the early morning hours of November 10, 1976.

FIGURE 7. Site 8, November 12, 1976 at approximately 0900.

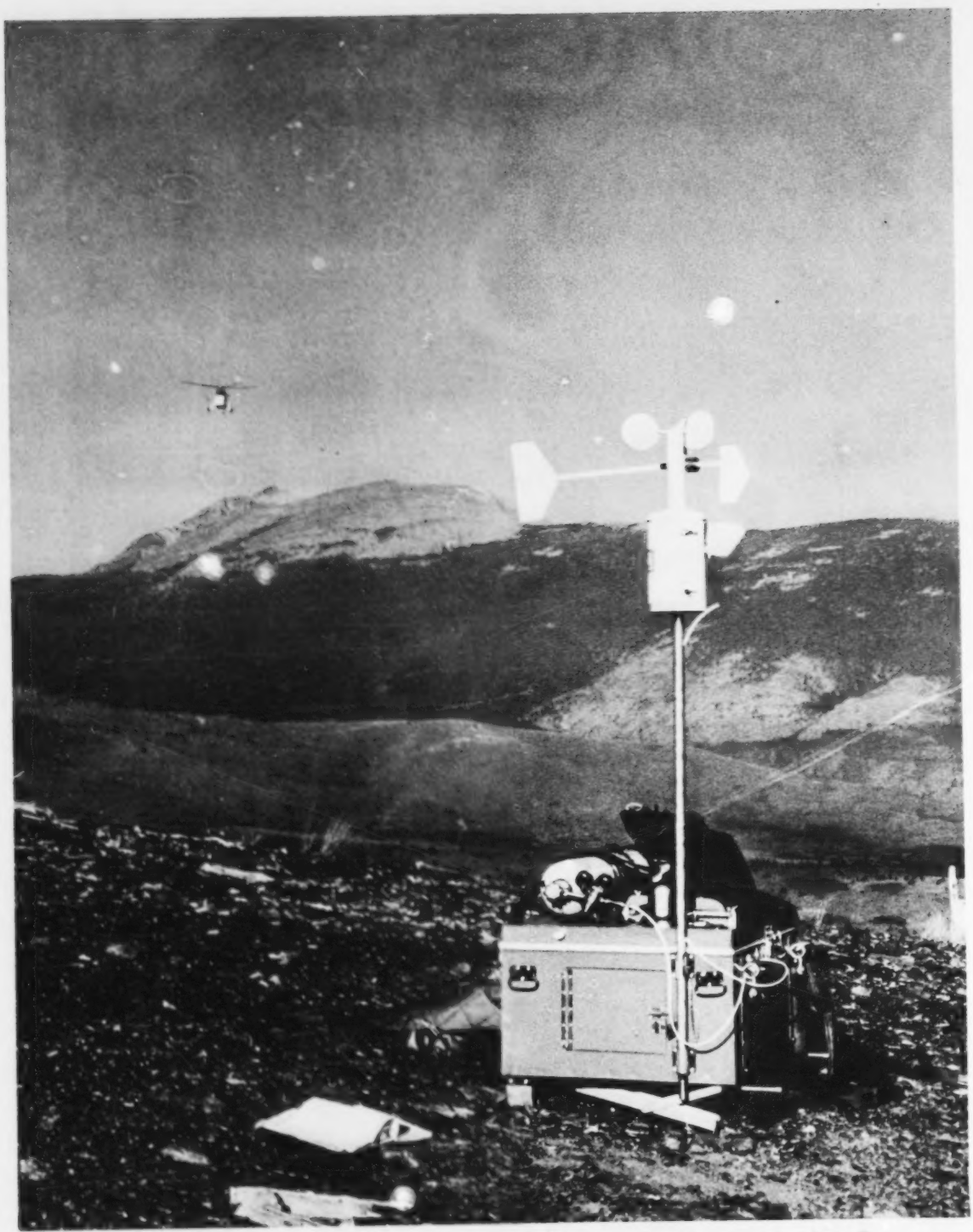

FIGURE 8. H-34 helicopter on a low-level pass over site 8. November 12, 1976, 0900.

FIGURE 9. The Anaconda stack (lower right) and the plume extending into the Mill Creek valley. December 30, 1976, 0920.

FIGURE 10. Site 15, December 30, 1976, 1135.

FIGURE 11. The Anaconda plume "slides" into the Mill Creek valley area. 1600, November 14, 1976.

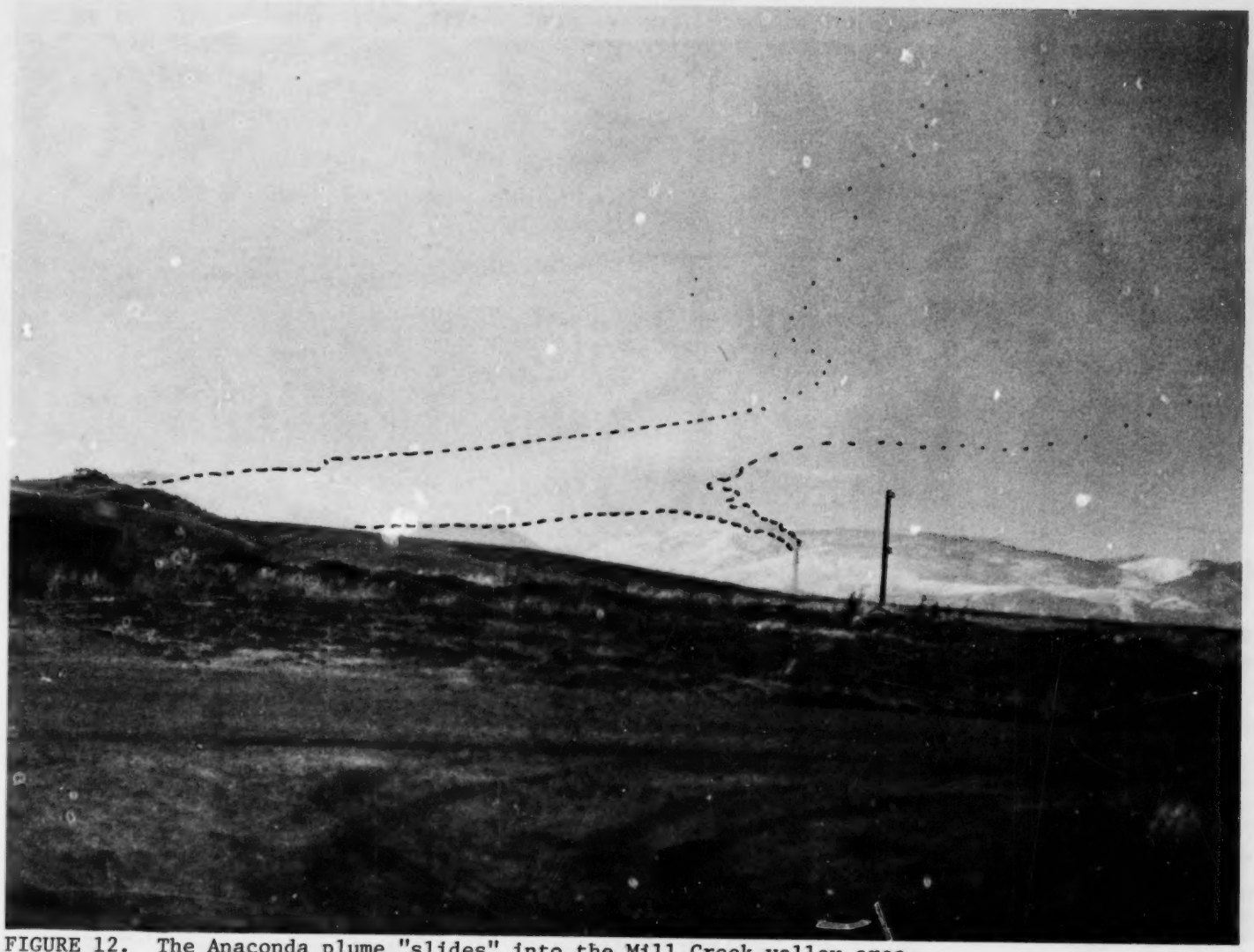

FIGURE 12. The Anaconda plume "slides" into the Mill Creek valley area. 1614, December 29, 1976.

FIGURE 13. The Anaconda plume "slides" into the Mill Creek valley area. 1435, January 1, 1977.

FIGURE 14. The Anaconda plume "slides" into the Mill Creek valley area. January 8, 1977, 1558.

FIGURE 15. The Anaconda plume begins to shift towards Mill Creek valley at 1730, February 5, 1977.

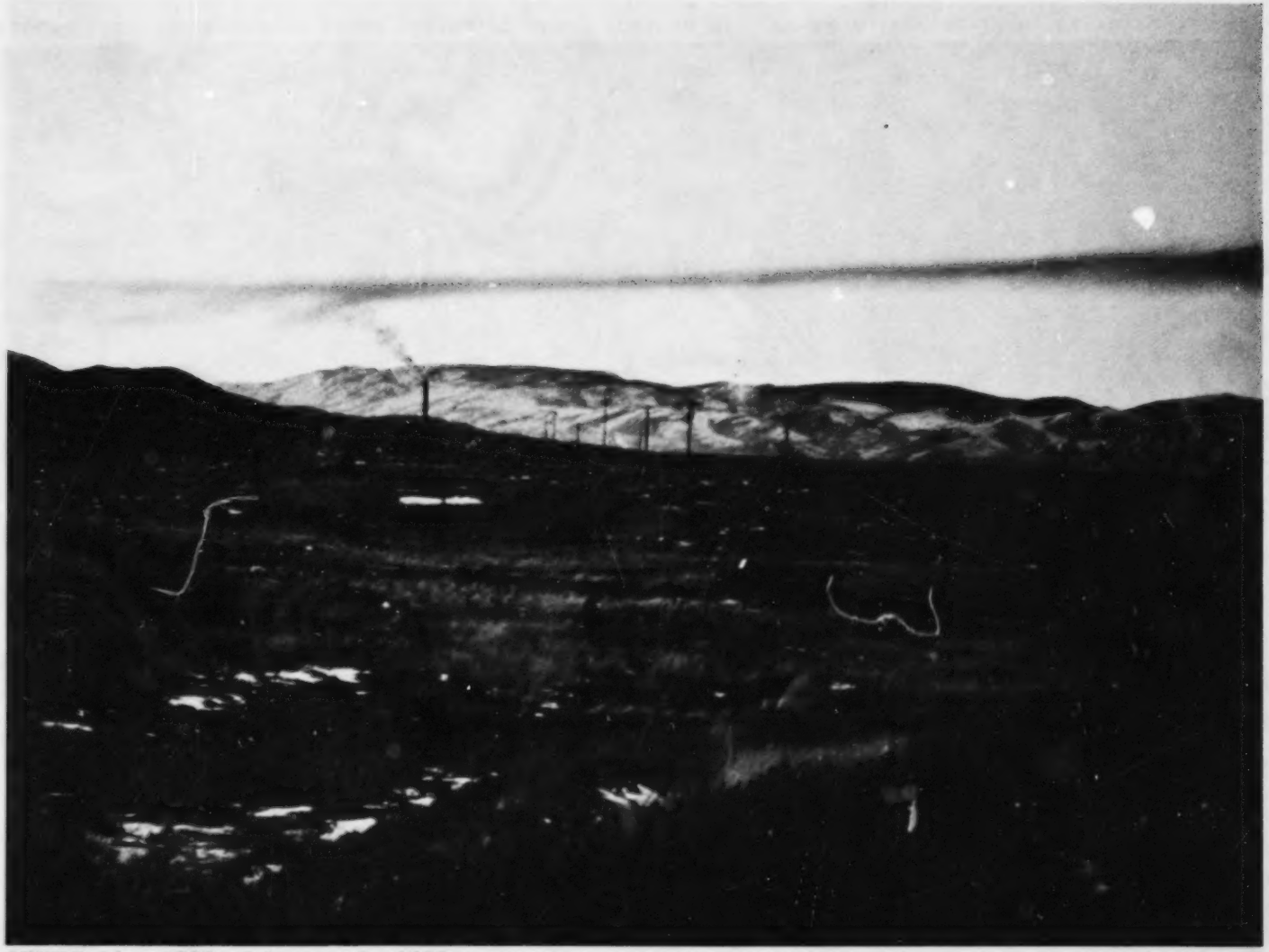

FIGURE 16. 1755, February 5, 1977.

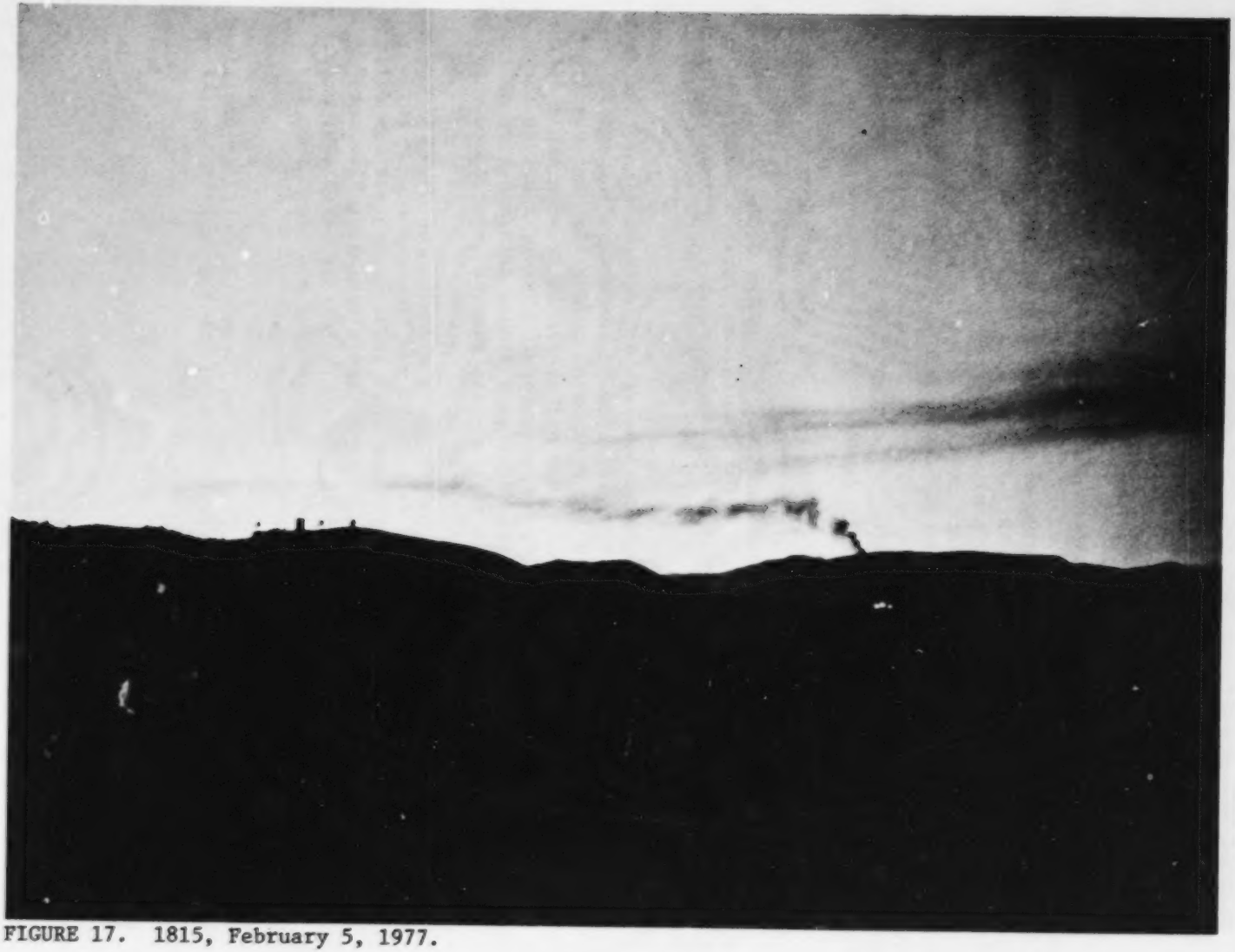

FIGURE 17. 1815, February 5, 1977.

RESULTS AND DISCUSSION

The maximum SO_2 concentrations recorded at each of the 17 monitoring sites (Figure 2) are listed in Table 3. (Peak concentrations of SO_2 as well as hourly averages of wind speed, wind direction, temperature, and SO_2 for each site are contained in Appendix A.) Three violations of the 3-hour Federal secondary SO_2 standard (0.5 ppm) were recorded during the study. Three violations of the 24-hour Federal primary SO_2 standard (0.14 ppm) were also recorded during the study. The documented violations of the standards are, in all probability, low because a truly representative measurement of the maximum ground-level, plume-centerline SO_2 concentration (used in mathematical dispersion models) was not possible for a number of reasons.

Although every effort was made to minimize the time required to react to an observation of the plume touching the ground, it was virtually impossible to obtain ground-level SO_2 measurements at the moment the plume first began to impact the ground. The effect would be to reduce the reported average sulfur dioxide concentration for the period of time an area was being impacted by the plume.

Throughout the study, the mobile SO_2 package was located within the area being impacted by the plume largely by reliance on subjective judgement. Except for a few occasions when EPA's instrumented H-34 helicopter was flying through the plume, the instrumentation was not available to accurately define the area of maximum ground-level SO_2 concentration. Most of the time the package was located in an area on the basis of a visual determination of the plume centerline, or on the strength of the taste that is experienced when a person is exposed to high concentrations of SO_2.

On several occasions, it was impossible to position the mobile SO_2 package within a desired area because a suitable landing site did not exist. These occasions are noted in Appendix A (under individual site "Comments" sections), but they are not reflected in Table 3. In this particular case, there is little doubt that the reported concentrations are lower than the actual ground-level, plume-centerline concentrations.

Particular attention should be paid to the "Comments" sections contained in Appendix A. Significant factors that may have (or did have) an impact on the collected data are described for each sample site.

An example of the difficulty in quickly responding to somewhat unpredictable changes in the plume is illustrated in Figures 11-17. As a whole, the photographs document what proved to be a frequent meteorological phenomena. The photographs were taken on different days from the grounds of the Fairmont Hot Springs Resort. The photographs are all quite similar. In each case, light winds had blown the plume to the northeast, or east during the day. (Evidence of this can be seen in the photographs as a stable plume layer extending from the upper right hand corner to the left center of the photograph). At approximately 4:00 PM (approximately 1 hour before sunset), on each separate occasion, lower level winds in the vicinity of the smelter began to blow strongly towards the Mill Creek valley. (Small stacks on the smelter property and fugitive emissions were used to make this observation). Often, for a period of 15 to 30 minutes the plume could be seen blowing in two different directions. The plume would begin to travel towards the Mill Creek valley as it left the stack; then, the plume would begin to blow back towards the northeast, or east, at the higher elevations.

Within 1/2 to 1 hour after the plume first began to shift, the plume would be blown into the Mill Creek valley by strong winds with remnants of the plume sliding into the valley. Unfortunately, the portable package was never used to measure the resulting plume concentrations in the Mill Creek valley because the phenomenon was unpredictable, and it usually occurred late in the day when it became hazardous to use the helicopter in the mountainous terrain. Thus, the only record of the phenomenon is a pictorial one.

TABLE 3. MAXIMUM SULFUR DIOXIDE CONCENTRATIONS RECORDED AT EACH SITE

Date of Occurrence	Site Number	Time Of Occurrence	Coordinates: Distance to Stack (miles)	Coordinates: Direction to Stack (degrees)	Wind: Speed (mph)	Wind: Direction (degrees)	Maximum Concentrations of SO_2: Instantaneous (ppm)	Maximum Concentrations of SO_2: Average Max. 1-hr (ppm)	Maximum Concentrations of SO_2: Average Max. 3-hr (ppm)
10-26-76	1	1500-1700	2.2	305	20	305	0.47	0.07	0.02 (a)
11-05-76	3	1000-1130	2.5	230	13-17	150	0.3		
11-06-76	4	1237-1500	1.6	210	(i)	(i)	2.2	0.8	0.3 (b)
11-10-76	5	0900-1200	4.8	05	6	340-360	0.60	0.16	0.06 (c)
11-11-76	6	0600-0700	5.2	32	3	115	0.07	0.01	
11-11-76	7	1700-2000	6.8	50	2	30-45	>5.0	>1.92	>0.7 (d)
11-12-76	8	2300-0200	6.8	50	2-6	35-45	>5.0	>1.16	>0.8 (d)
11-12-76	8	0900-1200	6.0	30	1-4	35-45	13.1	4.7	1.8 (e)
11-15-76	10	0900-1200	1.9	235	(i)	(i)	0.1	0	0
11-16-76 to 11-17-76	11	1000-0900	3.6	∿220	3-17	135-195	1.7	0.55	0.5 (f)
11-17-76	11	1100-1400	3.6	∿220	16-20	165-175	2.9	0.64	0.39
12-8-76 to 12-9-76	12	2300-0100	2.3	228	20	200-240	0.92	0.03	0.02
12-9-76 to 12-10-76	13	1200-0800	1.9	285	(i)	(i)	1.4	0.33	0.26
12-29-76	14	1800-2100	6.6	50	2-4	0-120	1.8	0.96	0.44
13-30-76	14	0500-0800	6.6	50	4-6	30-75	0.28	0.04	0.02
12-30-76	15	1145-1525	6.6	29	7-10	345	1.43	0.76	0.42
12-30-76 to 12-31-76	16	1613-1545	5.0	18	0.5-7.0	255-25	1.07	0.39	0.24 (g)
02-08-77	17	1237-1300	6.4	70	3.3	255	0.8	0.53 (h)	- - -

NOTES: Wind speed and direction were measured at the monitoring site.
The metric system of units has not been used in this report since the data used in this report were not recorded in metric units. (See page viii for list of conversions.)

a. 0.02 ppm 3-hour average computed from beginning of sampling (1530) to 1630; the 0.07 average (listed as a 1-hour average) is actually a ½-hour average computed from 1530-1600.
b. Represents 2.4-hour period of record; other 0.6-hour SO_2 concentrations assumed to be zero.
c. Represents 2.8-hour period of record; other 0.2-hour SO_2 concentrations assumed to be zero.
d. Instrument off-scale (>5.0 ppm).
e. 24-hour average = 0.24 ppm, 11/12 0900 to 11/13 0900, assuming (SO_2) = 0 for 11/12 1500-11/13 0900.
f. 24-hour average = 0.24 ppm, 11/16 1000 to 11/17 1000.
g. 24-hour average = 0.21 ppm.
h. Average reading is not an hourly average. The average is for the period 1237-1300.
i. Wind information is not available because of problems with the meteorological sensor package.

REFERENCES

Johnson, F. G., N. J. Cimon, and D. T. Mage, "Airborne Measurements of a Copper Smelter Plume in Montana, Anaconda Copper Company, Anaconda, Montana, October 1-December 9, 1976," U. S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada, 1978.

O'Boyle, C. J., personal communication, U. S. Environmental Protection Agency, Region VIII, Denver, Colorado, 1977.

The Anaconda Company, "Calculations of Ambient Sulfur Dioxide Concentrations Resulting from Operations at the Anaconda Reduction Works," Environmental Engineering Department, Butte, Montana, 1971.

APPENDIX A

INDIVIDUAL SITE SUMMARIES

The location of each monitoring site listed in the following tables is represented by a distance (in statute miles) and a bearing (in degrees, true north) from the Anaconda stack. The elevation of each site is given in feet above mean sea level (MSL). All of the monitoring sites were located on a U.S. Geological Service topographic map. The location and elevation of a monitoring site were obtained and verified using the topographic maps.

Meteorological information at each site was measured and recorded with a MRI Model 1072 mechanical weather station. Since the instrument records wind speed in miles of wind run per unit time, wind direction in degrees (referenced to true north) and temperature in degrees fahrenheit, no attempt was made to convert these units to the preferred metric units.

Sulfur dioxide concentrations are reported in parts per million (ppm) measured against a calibration standard that was calibrated in terms of ppm at reference conditions (25° C, 760 mm Hg).

Sulfur emission data for the smelter was obtained, through the courtesy of EPA Region VIII, from the strip charts and written records of The Anaconda Company. Since in-stack measurements of the SO_2 concentrations, stack temperatures, and stack velocity are not routinely made in the main Anaconda stack, the sulfur emission data represents a best estimate rather than a measured value. Inquiries on the computation of the sulfur emission data should be directed to the U.S. EPA, Region VIII.

When violations of the Federal primary and secondary standards for SO_2 were measured, the time of the violation and the recorded concentration are listed separately in each table. The applicable primary SO_2 standard for this study is 0.14 ppm for a period of 24 hours. The applicable secondary standard is 0.50 ppm for a 3-hour period.

General comments that would be useful in understanding and interpreting the data recorded at each site have been taken from the project notebook. The project notebook was maintained by the project officer, Jeffrey van Ee.

TABLE A-1

SITE NUMBER: 1 DATE: 10/26-27/76

ELEVATION: 5200 feet LOCATION: 2.2 mi, 305°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1300-1400	--	--	--	--	--	--
1400-1500	--	--	--	--	--	--
1500-1600						35
1510-1600**	20	305	48	0.07*	0.47	
1600-1700	19	305	46	0.04	0.39	46
1700-1800	17	275	45	0	0	--
1800-1900	13	305	43	0	0	--
1900-2000	9.5	230	41	0	0	--
2000-2100	9	230	40	0	0	--
2100-2200	7.5	235	39	0	0	--
2200-2300	7	220	37	0	0	--
2300-2400	9.5	230	37	0	0	--
2400-0100	9.5	235	37	0	0	--
0100-0200	4.5	200	37	0	0	--
0200-0300	4	195	35	0	0	--
0300-0400	10	185	35	0	0	--
0400-0500	10	215	35	0	0	--
0500-0600	8.5	200	35	0	0	--
0600-0700	10.5	180	35	0	0	--
0700-0800	6	165	34	0	0	--
0800-0900	10.5	175	33	0	0	--
0900-1000	11.5	175	36	0	0	--
1000-1040	9.5	195	40	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* Sulfur dioxide sampling began at 1530. The average concentration was computed for this period. Meteorological measurements began at 1510.

** Indented times are used to designate time periods which did not begin on the hour or half-hour. Emission data is unavailable for those time periods.

TABLE A-2

SITE NUMBER: 2 DATE: 10/29/76

ELEVATION: 5800 feet LOCATION: ∿ 4.2 mi, ∿ 135°

No meteorological data are reported.

Problems encountered with the SO_2 instrument.

TABLE A-3

SITE NUMBER: 3 DATE: 11/5/76

ELEVATION: 5080 feet LOCATION: 2.5 mi, 230°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0800-0900	--	--	--	--	--	64
0900-1000						58
1000-1100	--	--	--	--	--	58
0942-1042	13	150	52	*	0.3	
1100-1200	--	--	--	--	--	33
1040-1142	17	150	54	*	0.3	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* Instrument was in calibration during this period. The concentration of 0.04 ppm was computed from 1000-1130.

Comments: The instrument package was sited after the plume was observed hitting the ground in the vicinity of the Anaconda airport. The H-34 helicopter was called in from Butte at approximately 1000-1030 to begin making aerial plume measurements. The H-34 crew reported, upon arriving at the site, that the package was not being impacted significantly by the plume, and it should be moved closer to the plant. The package was subsequently moved to Site 4.

TABLE A-4

SITE NUMBER: 4 DATE: 11/05-06/76

ELEVATION: 5080 feet LOCATION: 1.6 mi, 210°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1030-1130	--	--	--	--	--	55
1130-1230	--	--	--	--	--	37
1230-1330	--	--	--	--	--	45
1237-1300	*	*	*	0.78†‡	2.2‡	
1300-1400	*	*	*	0.27	0.87	
1330-1430	*	*	*			49
1400-1500	*	*	*	0.31	1.3	
1430-1530	*	*	*			55
1500-1600	*	*	*	0	0	
1600-1700	*	*	*	0	0	
1700-1800	*	*	*	0	0	
1800-1900	*	*	*	0	0	
1900-2000	*	*	*	0	0	
2000-2100	*	*	*	0	0	
2100-2200	*	*	*	0	0	
2200-2300	*	*	*	0	0	
2300-2400	*	*	*	0	0	
2400-0100	*	*	*	0	0	
0100-0200	*	*	*	0	0	
0200-0300	*	*	*	0	0	
0400-0500	*	*	*	0	0	
0500-0600	*	*	*	0	0	
0600-0700	*	*	*	0	0	
0700-0757	*	*	*	0	0	

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* No meteorological data are available at the site. The MRI weather station strip chart motor was not turned on. The ambient temperature varied from 35° F to 60° F.

† Average reported for the 23-minute period only.

‡ An adjustment has been made to account for the high SO_2 readings resulting from the instrument being switched from the calibration mode to sample mode.

TABLE A-4 (Continued)

SITE NUMBER: 4 DATE: 11/05-06/76

ELEVATION: 5080 feet LOCATION: 1.6 mi, 210°

Comments: (Cont.) The instrument package was sited at Site 4 on the basis of SO_2 readings obtained from the H-34 helicopter. Difficulties were encountered with the SO_2 instrument chart recorder at the initiation of sampling at the site. These problems were corrected after some delay.

At 1630 the plume was observed impacting the ground in the vicinity of the site. The decision was made to leave the box out over night.

At 1900 the plume was observed to have moved off the site.

At 0700, 11/06/76 the plume was observed blowing towards the west-southwest. The package was subsequently moved off the site. In the process, a lift cable broke and the instrument package was roughly transported back to the airport facility at Butte for repair. It was discovered that the SO_2 instrument photomultiplier tube had become damaged during the movement of the package off the site. Repair of the instrument package was finished that evening.

TABLE A-5

SITE NUMBER: 5 DATE: 11/10/76

ELEVATION: 6840 feet LOCATION: 4.8 mi, 05°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0700-0800	--	--	--	--	--	47
0800-0900	--	--	--	--	--	47
0900-1000	7	345	35	0.16*	0.60	35
1000-1100	7	340	32	0.03	0.21	11
1100-1200	6	360	35	0.02	0.08	11
1200-1300	5	360	37	0	0	--
1300-1400	4	030	39	0	0	--
1400-1500	7	340	35	0	0	--
1500-1517	0.5	325	32	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* Sulfur dioxide average concentration computed from 0911-1000.

Comments: The plume was observed blowing into the Mill Creek-Wisdom Road area at daybreak. The helicopter was called in between 0700 and 0715. The plume in the area of the site was difficult to see distinctly. It appeared that the plume may have been hitting the saddle to the west of the site. The H-34 helicopter was called in and it arrived in the area at approximately 1000. The H-34 crew quickly reported that the plume was not impacting the site, but the plume may shift back to the site. The H-34 helicopter did manage to obtain a few measurements over the instrument package before the plume shifted. At 1600 it was obvious that the plume was not, and probably would not, impact the site. The instrument package was subsequently moved to Site 6 in an effort to anticipate where the plume might impact next.

TABLE A-6

SITE NUMBER: 6 DATE: 11/10-11/76

ELEVATION: 6730 feet LOCATION: 5.2 mi, 032°

Time	Wind		Temp. (°F)	SO_2 Conc.		Sulfur Emissions (1000 lbs/hr)
	Miles Run	Direction		Average (ppm)	Peak (ppm)	
1626-1700	2.5	60	36	0	0	--
1700-1800	4	60	34	0	0	--
1800-1900	5	60	33	0	0	--
1900-2000	5	120	32	0	0	--
2000-2100	2	195	31	0	0	--
2100-2200	2	210	30	0	0	--
2200-2300	0	Calm	30	0	0	--
2300-2400	8	195	29	0	0	--
2400-0100	5.5	195	29	0	0	--
0100-0200	4.5	195	29	0	0	--
0200-0300	2	225	28	0	0	--
0300-0400	4.5	195	27	0	0	--
0400-0500	1.5	30	27	0	0	51
0500-0600	3	195	26	0	0	73
0600-0700	3	115	27	~0.01	0.07	64
0700-0800	1	30	26	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

Comments: This site was chosen because it appeared to offer the best chance of being impacted by the plume under the existing meteorological conditions. At daybreak on 11/11/76 the plume was again observed to be heading into the Wisdom Highway-Mill Creek area. The H-34 helicopter crew reported that the plume was not hitting the site; that the plume was hitting the Grassy Mountain slopes. The Huey helicopter was called in to move the box to another location. By the time the instrument package was ready to be moved the plume began to lift and swing further towards the west.

TABLE A-7

SITE NUMBER: 7 DATE: 11/11-12/76

ELEVATION: 7400 feet LOCATION: 6.8 mi, 050°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1400-1500	--	--	--	--	--	23
1500-1600	--	--	--	--	--	40
1600-1700	2.5	315	30	0.09*	0.12	34
1700-1800	1	45	29	0.09	0.33	58
1800-1900	2	30	29	0.01	0.14	67
1900-2000	2	45	29	>1.8	>5.0	75
2000-2100	3.5	30	29	0.01	0.07	73
2100-2200	3	30	29	0	0	46
2200-2300	3.5	40	29	0	0	52
2300-2400	3.5	60	29	0.69	1.93	72
2400-0100	4	45	22	0.50	2.02	51
0100-0200	6	35	22	>1.16	>5.0	64
0200-0300	2	45	22	0.13	0.40	79
0300-0400	3	45	22	0	0	49
0400-0500	3.5	30	23	0.10	0.11	67
0500-0600	4	0	24	0	0	--
0600-0700	3	25	24	0	0	--
0700-0800	3	30	22	0	0	--

AMBIENT AIR VIOLATIONS:

TIME	AVERAGE CONCENTRATION
1700-2000	>0.63
2300-0200	>0.77
1600-1600	>0.19†

* Average concentration computed for 1636-1700 period.

† Assumed 0 ppm SO_2 during periods when no sampling occurred.

Comments: At approximately 1430 the plume was observed bending over towards the Mill Creek valley area. (The plume had been blowing out, earlier, over the valley.) By the time the instrument package was ready to be moved into the valley, the plume was observed blowing, generally, over the town of Anaconda. Light winds allowed for an appreciable plume rise.

TABLE A-7 (Continued)

SITE NUMBER: 7 DATE: 11/11-12/76

ELEVATION: 7400 feet LOCATION: 6.8 mi, 050°

Comments: (Cont.) Site 7 was chosen on the assumption that winds would remain light during the night and shift to a more northerly direction; thus bringing the plume across the high elevation site. (The plume was previously observed in this area so that site appeared to be reasonable.)

At daybreak on 11/12/76 the plume was clearly observed to be missing the site.

TABLE A-8

SITE NUMBER: 8 DATE: 11/12/76

ELEVATION: 6750 feet LOCATION: 5.7 mi, 030°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0700-0800	--	--	--	--	--	47
0800-0900	--	--	--	--	--	78
0900-1000	0.75	45	33	4.72	13.1	66
1000-1100	2.5	45	29	0.69	2.3	57
1100-1200	2.5	35	29	≈0.17	0.17	16
1200-1300	3.5	30	30	0.09	0.17	40
1300-1400	5.5	0	30	≤0.01	0.04	46
1400-1500	6	0	30	<0.02	<0.02	55
1500-1519	1.5	0	30	<0.01	≤0.01	--

AMBIENT AIR VIOLATIONS:

TIME	AVERAGE CONCENTRATION
0900-1200	1.9 ppm
0900-0900	0.25 ppm*

* Assuming 0 ppm during the period when no sampling occurred.

Comments: The H-34 crew reported just after daybreak that the instrument package at Site 7 was not in the plume. The plume was observed to be hitting the mountains identified later as Site 8. The instrument package was dropped at Site 8 - slightly off the top of the ridge identified by the H-34 helicopter crew as having the highest SO_2 concentrations. The Huey helicopter crew found it necessary to don their gas masks.

At the time the instrument package was dropped the plume had lifted and shifted to the west. The plume layer existing at Site 8 can best be described as a plume remnant.

Winds at the site were absolutely calm, initially. After the SO_2 instrument had been calibrated, the H-34 helicopter began to make a number of traverses over the site. On the last, and lowest, pass by the H-34 the wind was observed to pick up. Approximately one minute after the helicopter traverse the wind had died down to zero. The SO_2 concentration was observed to decrease from approximately 13 ppm to 6 ppm during this period. Shortly after this event, the Huey helicopter returned

TABLE A-8 (Continued)

SITE NUMBER: 8 DATE: 11/12/76

ELEVATION: 6750 feet LOCATION: 5.7 mi, 030°

Comments: (Cont.) to a landing spot approximately 150-200 feet up the hillside to pick up the ground crew. During the rest of the morning, the main plume gradually lifted until it was observed at 1145 to be just impacting the top of Grassy Mountain.

At 1200, the SO_2 instrument was checked to see what concentration of SO_2 existed in the area of Site 8. Since some SO_2 was still present, the instrument package was left at the site. The instrument range was decreased to 1 ppm (full scale).

At 1520 the SO_2 instrument was post-calibrated. No SO_2 was detected in the area at that time.

TABLE A-9

SITE NUMBER: 9 DATE: 11/12-13/76

ELEVATION: 7200 feet LOCATION: 6.5 mi, 030°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1610-1700	3	315	30	0	0	--
1700-1800	2	15	30	0	0	--
1800-1900	2	45	30	0	0	--
1900-2000	1	variable	29	0	0	--
2000-2100	1	variable	29	0	0	--
2100-2200	1	variable	26	0	0	--
2200-2300	3.5	135	25	0	0	--
2300-2400	3.5	25	25	0	0	--
2400-0100	6	135	25	0	0	--
0100-0200	8.5	130	20	0	0	--
0200-0300	10.5	135	19	0	0	--
0300-0400	13	135	18	0	0	--
0400-0500	15	135	16	0	0	--
0500-0600	13	135	15	0	0	--
0600-0700	14	135	15	0	0	--
0700-0800	14	135	15	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

Comments: This site was chosen on the basis of an educated guess that the plume might impact the area during the night.

TABLE A-10

SITE NUMBER: 10 DATE: 11/15/76

ELEVATION: 5080 feet LOCATION: 1.9 mi, 235°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0847-0900	*	*	*	0	0	--
0900-1000	*	*	*	0	≤0.05	--
1000-1100	*	*	*	0	0.1	--
1100-1200	*	*	*	0	0.1	--
1200-1300	*	*	*	0	0	--
1300-1400	*	*	*	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATIONS

NONE

* No meteorological data are available at the site. The mechanical weather station strip chart was not turned on. The ambient temperature ranged from 42° F to 50° F. Wind direction varied from 180° to 300°.

Comments: Strong southwesterly winds brought the plume over the smelter tailings ponds to the valley floor at daybreak. The H-34 helicopter crew reported the plume hitting the surface of the tailings ponds near the stack. This area appeared to be unsuitable for placement of the package because of an unsure foundation for the package and because the area was within a restricted area on the smelter property.

The package was sited in an area that appeared to be a likely place for the plume to impact. One-half hour after placement, the H-34 helicopter crew reported that the instrument package appeared to be located outside the plume. Later in the morning, the plume had shifted to an easterly direction. The instrument package was taken back to the base of operations in the afternoon to be readied for more promising meteorological conditions.

TABLE A-11 (#1)

SITE NUMBER: 11 (#1) DATE: 11/16-17/76

ELEVATION: 5020 feet LOCATION: 3.6 mi, ∿220°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0800-0900	--	--	--	--	--	72
0900-1000	--	--	--	--	--	72
1000-1100	--	--	--	--	--	62
0958-1100	13	180	44	0.44*	1.4	
1100-1200	11	180	43	0.47	1.4	59
1200-1300	12	180	44	0.49	1.3	42
1300-1400	17	180	44	0.12	0.39	22
1400-1500	14	165	43	0	0	10
1500-1600	10.5	165	44	0	0.04	10
1600-1700	8.5	180	46	0.10	0.39	31
1700-1800	11.5	180	43	0.20	0.48	39
1800-1900	11.5	165	44	0.23	0.58	39
1900-2000	10	165	44	0.28	0.77	46
2000-2100	11	180	44	0.55	1.3	70
2100-2200	8	195	44	0.24	0.77	60
2200-2300	2.5	Variable	42	∿0.05	0.10	61
2300-2400	2.5	165	41	<0.05	0.05	73
2400-0100	4.5	165	43	0.14	0.58	81
0100-0200	7.5	135	43	0.43	1.4	86
0200-0300	10.5	150	43	0.26	0.87	70
0300-0400	6.5	165	43	0.34	0.96	70
0400-0500	9.5	165	43	0.11	0.77	71
0500-0600	15.5	165	42	0.43	1.6	71
0600-0700	11.5	165	41	0.16	1.2	∿79
0700-0800	10	165	40	0.70	1.7	∿70
0800-0900	10	150	41	0.07	1.1	∿75
0900-0910	4	140	42	--	--	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

1000-1000 0.24 ppm†

* Sulfur dioxide values reported from 1014-1000. Average concentration computed for this time period.

† Assuming 0 ppm during the period when no sampling occurred.

TABLE A-11 (#1) (Continued)

SITE NUMBER: 11 (#1) DATE: 11/16-17/76

ELEVATION: 5020 feet LOCATION: 3.6 mi, ~220°

Comments: At daybreak the plume was observed hitting the ground to the east of the plant. Approximately 1 hour later the plume had shifted towards the Anaconda airport. Falling snow and clouds were in the mountains to the west. The H-34 helicopter crew reported that the maximum SO_2 concentration was right over the middle of the airport.

The plume was observed blowing towards the site throughout the day and into the night. The H-34 crew reported early the next day that the instrument package was still being impacted by the plume. The SO_2 instrument was calibrated at 0910. At this time the plume appeared to be swept downward over the tailings pond and then off towards the west, missing the site. Some consideration was given to moving the package, but with the strong southwesterly winds there appeared to be a good chance that the plume would again move back towards the site.

TABLE A-11 (#12)

SITE NUMBER: 11 (#2) DATE: 11/17-18/76

ELEVATION: 5020 feet LOCATION: 3.6 mi, ∿220°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0900-1000	--	--	--	--	--	79
0916-1000	12.5	160	49	0.02*	0.1	
1000-1100	18	160	52	0.01	0.1	62
1100-1200	19.5	165	55	0.31	2.65	67
1200-1300	17.5	175	57	0.64	2.9	
1300-1400	15.5	170	58	0.23	1.4	
1400-1500	14	160	59	0.02	0.29	
1500-1600	1.35	160	58	0.07	0.58	
1600-1700	8.5	160	57	0	0.1	
1700-1800	9	160	54	0	∿0.1	
1800-1900	4.5	160	52	0	0.1	
1900-2000	8.5	205	53	0	0	
2000-2100	8	220	54	0	0	
2100-2200	15	235	52	0	0	
2200-2300	14.5	230	48	0	0	
2300-2400	16	235	48	0	0	
2400-0100	6	165	48	0	0	
0100-0200	7	220	47	0	0	
0200-0300	2.5	0	43	0	0	
0300-0400	3.5	310	39	0	0	
0400-0500	3	310	38	0	0	
0500-0600	2	100	37	0.07	0.39	
0600-0700	5.5	205	38	0.07	0.19	
0700-0800	5	180	37	0	0	
0800-0900	2.5	310	38	0	0	
0900-0920	1.5	310	39	0	0	

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* Sampling began at 0930.

Comments: Sampling was resumed at 0930 after the SO_2 instrument was recalibrated at the site.

Light winds were prevalent during the early morning hours of 11/18/76. The plume rose almost straight out of the stack.

TABLE A-11 (#2) (Continued)

SITE NUMBER: 11 (#2) DATE: 11/17-18/76

ELEVATION: 5020 feet LOCATION: 3.6 mi, ∿220°

Comments: (Cont.) Sampling was terminated at the site at 0920. The SO_2 instrument was post-calibrated at 0930.

TABLE A-12

SITE NUMBER: 12 DATE: 12/8-9/76

ELEVATION: 5080 feet LOCATION: 2.3 mi, 228°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
0730-0830	--	--	--	--	--	57
0830-0930	--	--	--	--	--	36
0930-1000	6.5	195	46	0.01	0.23	
0930-1030	--	--	--	--	--	35
1000-1100	17.5	200	48	0.01	0.19	
1030-1130	--	--	--	--	--	52
1100-1200	18.5	200	50	0	0	
1200-1300	21	200	51	0	0	
1300-1400	19	195	52	0	0	
1400-1500	19	180	52	0	0	11
1500-1600	18.5	165	51	0	0	23
1600-1700	17	170	49	0.01	0.14	46
1700-1800	8.5	195	48	0.01	0.07	43
1800-1900	14	205	0.47	0.01	0.46	43
1900-2000	0.72	210	45	0.01	0.16	
2000-2100	21	195	45	0	0	
2100-2200	19.5	180	45	0	0	46
2200-2300	16	170	45	0	0	57
2300-2400	20	200	46	0.02	0.50	50
2400-0100	19	240	43	0.03	0.92	55
0100-0200	18	260	41	0	0	
0200-0300	11.5	290	41	0	0	
0300-0400	11.5	255	41	0	0	
0400-0500	10	250	40	0	0	
0500-0600	10	260	40	0	0	
0600-0700	11.5	270	39	0	0	
0700-0800	11	260	39	0	0	
0800-0900	11.5	270	39	0	0	
0900-0930	3	270	39	0	0	

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

Comments: The span drift that occurred during this period was not taken into account in the above figures.

TABLE A-12 (Continued)

SITE NUMBER: 12 DATE: 12/8-9/76

ELEVATION: 5080 feet LOCATION: 2.3 mi, 228°

Comments: (Cont.) During the instrument package pre-calibration, flights were made over the site by the H-34 and the lidar aircraft. Flights continued for a short time after the SO_2 instrument had been placed in operation.

On the morning of December 9, 1976, high winds brought the plume to the ground east of the smelter. The package was post-calibrated at 0930 and subsequently moved to Site 13.

TABLE A-13

SITE NUMBER: 13 DATE: 12/9-10/76

ELEVATION: 5160 feet LOCATION: 1.9 mi, 285°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1200-1300	*	*	*	0.21	0.70	--
1300-1400	*	*	*	0.05	0.16	28
1400-1500	*	*	*	0.31	1.4	37
1500-1600	*	*	*	0.33	1.4	60
1600-1700	*	*	*	0.13	1.5	61
1700-1800	*	*	*	0.06	0.18	63
1800-1900	*	*	*	0	0	44
1900-2000	*	*	*	0.02	0.25	65
2000-2100	*	*	*	0.01	0.04	70
2100-2200	*	*	*	0.03	0.09	66
2200-2300	*	*	*	0	0	49
2300-2400	*	*	*	0	~0.02	55
2400-0100	*	*	*	0.05	0.45	31
0100-0200	*	*	*	0.01	0.29	43
0200-0300	*	*	*	0	~0.02	--
0300-0400	*	*	*	0	0	--
0400-0500	*	*	*	0	0	--
0500-0600	*	*	*	0	0	50
0600-0700	*	*	*	0	0	36
0700-0800	*	*	*	0	0.04	28
0800-0900	*	*	*	0	0	--
0900-1000	*	*	*	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* The chart drive on the MRI weather station was not turned on. Thus, the only data obtained were the range of temperatures over the sampling period. Temperatures ranged from 32 to 38° F.

TABLE A-14

SITE NUMBER: 14 DATE: 12/29-30/76

ELEVATION: 7280 feet LOCATION: 6.6 mi, 050°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1600-1700						64
1700-1800						64
1745-1800	0.5	variable	27	0	0	--
1800-1900	2	135	26	0.11	0.16	50
1900-2000	3.5	120	25	0.97	1.8	~30
2000-2100	2.5	60	24	0.21	0.64	~60
2100-2200	2	360	22	0.14	0.48	58
2200-2300	3.5	345	23	0	0	--
2300-2400	4.5	345	23	0	0	43
2400-0100	3.0	90	22	0	0	46
0100-0200	4.0	45	21	0	0.05	50
0200-0300	3.0	135	20	0	0	--
0300-0400	4.0	30	20	0	0	50
0400-0500	6.0	0	19	0	0	61
0500-0600	5.0	60	17	0	0.05	76
0600-0700	6.0	75	15	0.04	0.28	50
0700-0800	4.0	30	15	0.01	0.18	58
0800-0900	5.5	75	14	0	0	--
0900-0930	2.5	75	14	0	0	--

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

Comments: At approximately 1600 the plume was observed to have shifted from blowing out over the valley to blowing into the Mill Creek valley area. By 1700 the plume had shifted back out of the area. Remnants of the plume were observed in the Mill Creek valley area at this time. Site 14 was located to the east and above the plume remnants. During the calibration of the SO_2 instrument, winds were light and variable. Site 14 was chosen with the hopes that remnants of the plume would be blown on to the site and that a shift in the winds during the night would bring the plume back into the valley. At 1930, the plume was observed to be blowing back into the Mill Creek valley area.

TABLE A-14 (Continued)

SITE NUMBER: 14 DATE: 12/29-30/76

ELEVATION: 7280 feet LOCATION: 6.6 mi, 050°

Comments: (Cont.) At daybreak, December 30, 1976, the plume was observed blowing into the Willow Creek valley area south of the smelter. The Huey helicopter was delayed in leaving Butte because the helicopter needed to be fueled.

Shortly after 0900, the helicopter was in the area south of the smelter. The plume was observed to spill over the continental divide and to also follow the valley to the south of the Fairmont Hot Springs Resort.

After picking up the instrument package at Site 14, the plume was observed to have shifted direction to the point where it was blowing over the saddle formed by "C" Hill and Weather Hill (to the south of the smelter).

TABLE A-15

SITE NUMBER: 15 DATE: 12/30/76

ELEVATION: 7200 feet LOCATION: 6.6 mi, 029°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1000-1100	--	--	--	--	--	45
1100-1200	--	--	--	--	--	51
1145-1200	--	345	15	0.33	>1.0	
1200-1300	--	345	15	0.76	1.43	59
1300-1400	8	345	15	0.44	1.27	50
1400-1500	10	345	15	0.10	0.33	41
1500-1600						48
1500-1525	7.5	345	15	0.38	0.38	

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

Comments: Erratic strip chart drive on the MRI weather station prevents a truly accurate analysis of the wind data.

Site 15 was chosen after flying around the Mill Creek valley area for some time. The haze present in the valley made it difficult to identify the plume centerline and its impaction point. It also appeared as if the formation of fog in the valley was being enhanced by the plume.

During the early afternoon, the plume appeared to lift. At 1525 the instrument was pre-calibrated and prepared for transport to a site that appeared to be more likely to be hit by the plume under the existing, and predicted, meteorological conditions.

TABLE A-16

SITE NUMBER: 16 DATE: 12/30-31/76

ELEVATION: 7280 feet LOCATION: 50 mi, 018°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1400-1500	--	--	--	--	--	41
1500-1600	--	--	--	--	--	48
1600-1700	--	--	--	--	--	50
1613-1700		0	14	0	0	
1700-1800	7	0	14	0.06	0.19	53
1800-1900	6	0	14	0.08	0.16	34
1900-2000	5	0	14	0.09	0.16	47
2000-2100	6.5	0	14	0.02	0.12	48
2100-2200	7.0	0	14	0.19	0.39	47
2200-2300	6.0	0	14	0.39	0.87	69
2300-2400	2	0	14	0.14	0.33	43
2400-0100	0	--	14	0.13	0.23	35
0100-0200	2.5	0	14	0.05	0.10	29
0200-0300	0.5	variable	15	0.02	0.05	39
0300-0400	1	0	15	0.01	0.05	33
0400-0500	0.5	0	15	0.06	0.10	51
0500-0600	0.5	0	15	0.04	0.10	55
0600-0700	1.0	255	15	0.05	0.07	57
0700-0800	1.0	255	15	0.03	0.05	49
0800-0900	1	255	15	0.02	0.05	50
0900-1000	0.5	variable	16	0.02	0.05	36
1000-1100	2.0	45	14	0.06	0.12	47
1100-1200	1.5	0	14	0.05	0.10	49
1200-1300	1	345	16	0.09	0.07	56
1300-1400	2.5	25	16	0.28	1.1	52
1400-1500	5.5	360	16	0.10	0.31	63
1500-1600						54
1500-1530	5.0	345	14	0.08	0.26	
1530-*					0.14	
1530-1600	5	345	14			
1600-1700	11.5	345	11			
1700-1800	8.5	345	9			
1800-1900	9.0	345	8			
1900-2000	7.5	345	7			
2000-2100	8.5	345	6			
2100-2200	8.5	345	5			
2200-2300	6.5	0	4			
2300-2400	6.5	0	4			

(Continued)

TABLE A-16 (Continued)

SITE NUMBER: 16

DATE: 12/30-31/76

ELEVATION: 7280 feet

LOCATION: 5.0 mi, 018°

Time	Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
2400-0100	5	0	4			
0100-0200	6	0	4			
0200-0300	5.5	0	4			
0300-0400	6	0	3			
0400-0500	4.5	15	3			
0500-0600	5	15	3			
0600-0700	5	15	3			
0700-0800	4	0	3			
0800-0900	5.5	0	2			
0900-1000	4.5	15	2			
1000-1100	4.5	15	1			
1100-1200	3	15	0			
1200-1244	1.5	15	-2			

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* Sulfur dioxide readings at the site beyond 1530 were made possible because the strip chart paper remained stuck to the paper roll even though the paper had run out. It is not possible to tell when the paper ran out or when the SO_2 instrument lost power, simply by looking at the strip chart record. The only reading that can be obtained is the peak SO_2 reading recorded before the power was lost to the instrument package.

Comments: Winds were predicted to be from the north during the evening of December 30, 1976. Site 16 was chosen because it lay as close to due south of the smelter as possible while retaining a high elevation.

Clouds and light snow prevented access to the instrument package on December 31, 1976. From time to time during the daylight hours of December 31, 1976, it was possible to see the plume being blown towards the mountainous area south of the smelter.

At approximately 1200, January 1, 1977, the snow and clouds had cleared to the point where the helicopter could make a landing at the site. The sample line was found to be clogged with snow.

TABLE A-16 (Continued)

SITE NUMBER: 16 DATE: 12/30-31/76

ELEVATION: 7280 feet LOCATION: 5.0 mi, 018°

Comments: (Cont.) Power to the SO_2 instrument had automatically turned off due to a low voltage on the battery, and the strip chart had run out on the SO_2 strip chart recorder. A post-calibration was not performed since the instrument had been off for an indeterminate length of time, and the calibration gas had leaked out of the cylinder.

At 1315 the plume was observed to be blowing out over the valley. The plume height was measured (with the helicopter) to be approximately 9400 feet MSL.

TABLE A-17

SITE NUMBER: 17

DATE: 02/08/77

ELEVATION: 8900 feet

LOCATION: 6.4 mi, 070°

Time	Wind Miles Run	Wind Direction	Temp. (°F)	SO_2 Conc. Average (ppm)	SO_2 Conc. Peak (ppm)	Sulfur Emissions (1000 lbs/hr)
1030-1130	--	--	--	--	--	62
1130-1230	--	--	--	--	--	67
1230-1330	--	--	--	--	--	56
1222-1237*	0.5	30	41	--	--	--
1237-1300	1.25	255	42	0.53†	0.8	--
1330-1430	--	--	--	--		33
1300-1352	2.5	255	43	0.21†	0.59	

AMBIENT AIR VIOLATIONS: TIME AVERAGE CONCENTRATION

NONE

* During this time period, the site was being inpacted by the plume. Due to the importance of documenting the meteorological conditions existing at the plume impaction site, the meteorological data are reported for the period when the SO_2 instrument was in calibration.

† Average reading is for the listed time period only.

Comments: At daybreak the plume appeared to be ready to head into the Mill Creek valley area. However, the winds never became quite strong enough to blow it into the area. Winds throughout the day were quite variable both in speed and direction.

At 1130 the plume was clearly observed from the Huey helicopter to be hitting the slope of Mount Haggin. Because of low fuel and heavy tree cover it was impossible to place the package in the center of the plume impaction area. (This area was identified later as the Clear Creek drainage.) Anticipating that the winds would increase, and the plume would lift, the instrument was sited on the eastern ridge of the Clear Creek drainage. The main portion of the plume appeared to hit the lower middle portion of the drainage; thus, site 17 was above and to the south of this area.

At the beginning of sampling, winds at the site were light and variable. When the winds were from the north, the SO_2 instrument would respond. When the winds shifted away from the Clear Creek drainage, the SO_2 instrument reading would drop.

TABLE A-17 (Continued)

SITE NUMBER: 17 DATE: 02/08/77

ELEVATION: 8900 feet LOCATION: 6.4 mi, 070°

Comments: (Cont.) By 1330 it was obvious that the winds had shifted to a southerly direction and that the plume would probably not re-enter the area in the foreseeable future. The instrument package was removed from the site after a post-calibration at approximately 1400.

APPENDIX B

DESCRIPTION OF THE ANACONDA SMELTER

The Anaconda smelter uses an electric furnace and a natural gas-fired reverbatory furnace in the production of primary copper. Emissions from the smelter are carried by natural convection through two separate flues to the base of the 178-meter stack. (Typical emission data are listed in Table 1.) The base of the stack is at an elevation of 5760 feet above sea level (203 m above the valley floor). An electrostatic precipitator located at the base of the stack removes particulates from the main flue. A portion of the emissions from the electric furnace are transported to a sulfuric acid plant before being transported through the "high velocity" flue to the stack. A bag house is used on the high velocity flue to remove particulates.

TABLE B-1. SOURCE CHARACTERISTICS[1]

Source:	Main Stack
Stack Height:	178 m, the stack is on a hill 203 m above the valley floor. The effective stack height would be 381 m.
Stack Diameter:	18.3 m
Exit Velocity[2]:	1.92 - 2.52 m/s
Flow Rate[3]:	505 - 661 m^3/s
Exit Temperature[4]:	337 - 370° K
Stack Concentration[5]:	1.7×10^6 - 16.4×10^6 $\mu g/m^3$

1 Furnished by Region VIII, U. S. EPA.

2 Based on stack area and flow rate.

3 Measured at 1000 daily.

4 Measured 41.15 m below stack top.

5 Based on exit velocity and emission rates.

APPENDIX C

DESCRIPTION OF THE LOCAL TOPOGRAPHY AND METEOROLOGY

The smelter is located approximately 2 miles southeast of the town of Anaconda (Figure 2). The town lies in one of the three mountain valleys which meet in the vicinity of the plant. A short, deep and narrow valley (Mill Creek valley) lies to the southwest of the plant. A long, broad valley lies to the northeast of the plant. (This valley runs in a north-south direction and it includes the towns of Warm Springs and Deer Lodge). Approximately eight miles southwest of the plant lies the high alpine area of Mount Haggin (10,607 feet). The effect of these topographical features on the local weather patterns is significant, but has not been adequately characterized to provide well-documented three-dimensional flow which could be used in diffusion modeling.

Invasions of Pacific polar maritime air and the influence of the local terrain are important factors in the local climatology. The climate in the Anaconda area is described as modified continental. Snowfall at the lower elevations is infrequent and light. Stable conditions are frequently observed during the winter months. Prevailing winds in the area are from the southwest. The only available meteorological information in the Anaconda area is obtained through the state and Anaconda pollution monitoring networks.

APPENDIX D

DESCRIPTION OF THE MOBILE SULFUR DIOXIDE INSTRUMENT PACKAGE

The mobile SO_2 instrument package was specifically designed by the Monitoring Operations Division (MOD) for use in the Anaconda, Montana, area during the harsh winter months. Sulfur dioxide data, wind speed and direction, and temperature were recorded on strip chart recorders. A MRI mechanical weather station was used to measure the meteorological parameters. A modified Thermo Electron Corporation (TECO) Model 43 instrument was used to measure sulfur dioxide. This information was recorded on an Esterline-Angus Minigraph recorder. The 120-volt AC power for the TECO 43 was supplied from an Advance Conversion Devices (Model A22-1) 12-volt DC inverter. Direct current power for the SO_2 instrument sample pump, the Minigraph recorder, and the TECO 43 was furnished by a silver-zinc battery. A canister of activated charcoal was mounted inside the insulated box for zeroing the SO_2 instrument. Attached to the top of the box was a size 100 cylinder of nominally 4 ppm SO_2 in air span gas. Attached to the bottom of the box were two scissors jacks for leveling the box on rough terrain. A 6-foot piece of pipe was carried on top of the box for the purpose of supporting the mechanical weather station and the 1/4-inch Teflon SO_2 sample line. Padlocks on both instrument access doors prevented unauthorized entry into the box. The total weight of the package was approximately 250 pounds.

The modified TECO 43 instrument has been used by MOD in aircraft for plume studies and wide-area air quality monitoring. Further modifications were required to reduce the power consumption and to insure stable operation under a wide variety of temperatures. A 12-volt DC diaphragm pump replaced the normal 120-volt AC instrument pump. The flow was reduced from the 6.4 lpm used in aircraft operations to 1.6 lpm using the factory-supplied glass capillary. Military grade integrated circuits were used to upgrade the electronic amplifier circuitry. To help insure stable instrument operation, power to the TECO 43 was maintained at all times. When the instrument was not out in the field, a 12-volt DC power supply powered the box. When the box was taken out into the field, power was transferred to the silver-zinc battery.

The silver-zinc battery was selected to power the instrument package for a number of reasons. Siver-zinc batteries have the highest energy density of any commercially available rechargeable battery; they have a low voltage drop during discharge, and they can operate quite well over a wide temperature range.

APPENDIX E

CALIBRATION PROCEDURES AND EQUIPMENT

Before and after every sampling period, the TECO 43 was zeroed and spanned at the sampling site. This information was recorded on the instrument strip chart recorder along with the sample data. The instrument was zeroed by allowing the instrument to pull air through the 8-ounce activated charcoal canister contained inside the instrument package. Span gas from the Scott-Marrin aluminum cylinder was introduced to the instrument through Teflon tubing and a stainless steel tee. A 0-5 lpm rotameter was used on the tee to insure that the span gas introduced to the instrument was at atmospheric pressure. A two-stage stainless steel regulator was used on the gas bottle to maintain a relatively stable flow.

The instrument would normally be zeroed using the 0.5 ppm scale. This helped to minimize the zero offset. For the initial instrument calibration, the zero suppression control was adjusted to give a zero reading on the panel meter. For the post calibration sequence the zero level was simply recorded. After several minutes had elapsed, the instrument range would be changed to 5 ppm. Span gas would be introduced, and (for the pre-calibration sequence) the span control would be adjusted until the panel meter read a nominal 4 ppm. After waiting for several minutes to insure that the instrument calibration was stable, the calibration tubing was disconnected and the sample line was connected. Events on the strip chart were "flagged" by noting the time of the event in the project notebook.

The mechanical weather station was aligned on True North using a magnetic compass and a magnetic declination of 19° east. Using the jacks on the instrument package, the weather station was leveled for proper operation.

APPENDIX F

QUALITY ASSURANCE PROCEDURES AND CALIBRATION STANDARDS

The MRI mechanical weather station temperature sensor was calibrated against a mercury thermometer that was compared against a National Bureau of Standards (NBS) traceable thermometer.

Calibration of the sulfur dioxide cylinders was performed by the Environmental Monitoring and Support Laboratory's technical support contractor, Lockheed Electronics Corporation (LEC). These cylinders were analyzed on several occasions using the Federal reference method for sulfur dioxide. Modifications were made to the Pararosaniline method to improve the precision of the analysis.* Analyses of the calibration atmosphere generated with a NBS permeation tube (maintained within a Bendix Dynamic Calibration System) demonstrated that the method employed by LEC was able to yield results within approximately three percent of the calculated NBS traceable concentrations.* Direct comparison of the cylinders to an NBS traceable calibration atmosphere (in the field) was hampered by difficulties in maintaining and monitoring the permeation tube environment.

Analysis of the sulfur dioxide cylinders performed before and after the study show that the low-level sulfur dioxide mixture remained stable throughout the study.* The lower values reported at the beginning of the study are attributable to the inexperience of the newly assigned chemist with the Federal reference method. Comparison of the analyses performed by LEC (near the end of the study period) and Scott-Marrin, Inc. show good agreement with each other.* This serves as another indicator of the quality of the analyses by LEC.

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* Lockheed Electronics Company, Inc. Summary of Results of the Anaconda Mission and Description of the Method Used for SO_2 Permeation Tube Analysis. Las Vegas, Nevada, April 18, 1977. 16 pp.

APPENDIX G

DATA ANALYSIS

On all strip chart records the accuracy of the strip chart drive motor was checked against the event times noted in the project log book. In the event that there was a discrepancy, a linear interpolation of the time between two events was assumed. Hourly averages for sulfur dioxide were computed using a planimeter. Hourly averages for the meteorological data were obtained using a clear plastic ruler to obtain equal areas above and below the line. In most cases, zero and span drift for the sulfur dioxide instrument were negligible (relative to the measured ambient concentrations), and it was ignored. In a few cases, sulfur dioxide data were corrected for instrument span drift by linear interpolation between the two instrument span points. In those cases where corrections could be made for zero drift, the lowest values recorded during a sample period helped establish the linear zero-drift baseline.

Throughout the entire study the sulfur dioxide instrument was spanned to 4 ppm. (This was the nominal value for all the sulfur dioxide tanks purchased for the study). Throughout the study the concentration of the tanks was measured to monitor any changes in the concentration of the calibration gas. At the end of the study, after a number of analyses had been performed on the tanks, a value was assigned to each tank used in the study. The mean values from the analyses performed before and after the study were averaged to obtain the final value used in the reduction of the strip chart data. For cylinder MM11330, the cylinder used for virtually the whole study, the sulfur dioxide concentration was determined to be 3.9 ppm. For cylinder MM11331, which was used during the latter portion of the study, the sulfur dioxide concentration was determined to be 4.0 ppm.

To obtain a more accurate representation of the Anaconda plume, adjustments have been made to the sulfur dioxide data obtained for the H-34 helicopter. (The TECO 43 time response characteristics have been used to adjust the data recorded on magnetic tape.) For ground-level, ambient air measurements, it is not customary to adjust the data for the instrument time response. As long as the instrument possesses the characteristics of an "equivalent method," no corrections are required. The TECO 43 used in the mobile package has been modified; hence, it is necessary to measure the resulting time response to confirm that it meets or exceeds the specifications required for a method to be designated as an "equivalent method". The time response measured in Anaconda was 103.5 seconds to 90% full scale for the rise time. The rise and fall times were equal. The lag time was approximately 4.5 seconds. Since

the modified TECO 43 possesses response characteristics which are better than, or equal to, those characteristics required for an "equivalent method", no adjustments were made to the data to obtain a more accurate representation of the Anaconda plume.